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CHINESE STUDY REDUCTION OF TURNAROUND TIME FOR FREIGHT CARS

/Comment: This report gives in full an article entitled "Comparative Analysis of Planned and Actual Turnaround Time of Freight Cars" by Tsung Chih-lung, published in the Jen-min T'ieh-tao (People's Railways), Vol II, No 6, June 1950.

Tsung points out the need to perfect the application of the formula for the calculation of turnaround time which has been employed for planning purposes, and stresses the need for more complete and reliable operational data.

For convenient reference, the following glossary of terms, definitions, and symbols has been prepared.

Glossary of Terms, Definitions, and Symbols

1. Turnaround Time (TRT)

On Chinese railways and in this article, the term is used in substantially the same sense as in the US, except that the cycle begins at the time a loaded freight car, in a made-up train, is dispatched on its journey. The present article is limited to a discussion of turnaround time for freight cars only.

In calculating turnaround time, the quantitative measure may be considered the figure expressed by the ratio between the total number of freight cars in operation and the number of cars which represent the average daily traffic volume, or average daily work load. This relationship may be explained by saying that on an independently operating railway, if the average daily work load is 500 cars, and the average turnaround time is 3 days, then the railway must have 1,500 cars in use to maintain regular operations on that scale. This simple relationship is introduced early in the article as a check against a more complicated formula which has been devised and used by the railway administration for technical analysis and planning of operations. In this formula, turnaround time is considered to be composed of: (1) travel time, (2) switching time, and (3) stopping time.

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2. Turnaround Distance (TRD)

The average turnaround distance is the average distance traveled per car during the turnaround time.

3. Travel Time (TT)

The travel time is the elapsed time from the dispatch of a loaded car until it reaches the station where it is to be unloaded, including incidental stops at way stations for taking on fuel or water, for lubrication, or for waiting on sidings; but excluding the time spent at intermediate switching points, regardless of whether or not the cars are actually switched.

4. Travel Speed (TS)

Travel speed is the distance traveled divided by the travel time. It is this figure which should be used in the denominator of the first component of the formula. It should not be confused with running speed, which is the distance traveled divided by the time that the cars are in motion, that is, travel minus the total duration of incidental stops at way stations. The factor, running speed, does not enter into the present calculations.

5. Average Distance Between Marshaling Yards or Switching Stations (DSM)

DSM is the aggregate of the distances between marshaling yards or switching stations divided by the number of spaces between these stations.

It is important to distinguish between DSM and SWD, which according to the author have been wrongly used interchangeably in the past, particularly in the turnaround-time formula. He asserts that the two are quite different.

6. Average Switching Distance (SWD)

SWD is the daily average total kilometrage of all cars in operation divided by the daily average number of cars switched. SWD is not the average distance which cars move when shunted around in a marshaling yard. This entity may be expressed by saying that of the daily average total kilometrage for every car switched, a definite average distance has been traveled, and this distance is what is meant by SWD.

With respect to the number of cars switched, the article indicates that empty cars as well as loaded cars may be included in the count; but by no means all of the empty cars handled in a switching station are actually switched, according to the author's use of the term. Some of them became empties after arrival, therefore their time in that station would be reckoned as stopping time. Just how to reckon the number of cars actually switched, whether loaded or empty, is shown by the use of diagrams, in Part IX, Section C.

The author asserts that SWD, instead of DSM, should be used in the denominator of the second term of the formula and that it will yield more accurate results in the calculations.

7. Average Switching Time (SWT)

This refers to the average time required to switch cars in the switching stations, and includes the whole period from the time of arrival at the staion to the time of departure. SWT has no direct relationship whatever to SWD. It should be noted that the text states that through cars passing through a switching station were counted as switched; but the author recommends that a shorter average switching time be applied to them.

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8. Daily Work Load (DWL)

This is understood to be the actual, or planned, (as the case may be) daily average of the volume of traffic handled, or to be handled, expressed in terms of the number of carloads. While ideally, this might be the daily car loadings, it is believed that in practice, the number of cars loaded may be greater. At times, many cars actually do not carry a full load, but at other times cars may carry more than the normal amount of cargo.

9. Average Stopping Time (ST)

The stopping time, as used in this article, consists of the interval required for the loading and unloading operations. This is construed as including the whole time that a car spends in the station, or stations, where loading and/or unloading operations take place.

10. Number of Cars Loaded (CLD)

11. Number of Cars Unloaded (CUN)

12. Double Phase Stopping Time Percentage (PC)

This refers to the average number of cars unloaded and then reloaded at the same station, expressed as a percentage of the average number of all the cars handled at the stopping stations.

13. Adjusted Average Stopping Time (AST)

14. Adjusted Average Switching Time (ASWT)

15. Adjusted Average Switching Distance (ASWD)

The article by Tsung follows:7

I. INTRODUCTION

In response to the call of the Central People's Government for the fulfillment of the transportation goals planned for 1950, every railroad worker is studying hard to make sure of the realization of these goals at his special post. To fulfill these goals, a matter of primary concern is the reduction of the turnaround time of freight cars, for if this can be accomplished, fewer freight cars can be used to transport the same amount of freight, or more freight can be transported with the same number of freight cars. For this reason much attention has been devoted to the subject of turnaround time, and its reduction has become a major objective.

II. PLANNED TURNAROUND TIME

Suppose a certain railroad bureau has a planned turnaround time (TRT) of 1.90 days. This figure is derived from the application of the following formula:

$$(TRT = \frac{1}{24}\left(\frac{TRD}{TS} + \frac{TRD}{DSM} \times SWT + \frac{CLD + CUN}{DWL} \times ST\right)$$

In this formula, in the first term inside the parentheses, the average turnaround distance (TRD), is divided by the travel speed (TS), and the value of this term represents the travel time (TT). In the second term, the average turnaround distance is divided by the average distance between marshaling yards or switching stations (DSM) and the quotient is multiplied by the average switching time (SWT), and the value of this term represents the total time spent in switching operations. In the third term, the number of cars loaded (CLD) plus the number of cars unloaded (CUN) is divided by the planned daily work load (DWL), then the quotient is multiplied by the average stopping time (ST); and the value of this term represents the total stopping time for loading and unloading. These three terms expressed in hours, added together and divided by 24 give us the complete turnaround time expressed in days and decimals thereof.

Let it be supposed that having computed the turnaround time for boxcars and multiplied it by the daily work load, it is found that the number of boxcars required for sustained operations is 1,385. Using the same method, assume that the number of gondola cars required is 1,323, flat cars 197, hopper cars 144, and tank cars 27. Adding these figures together, it is found that the total number of freight cars required for sustained operation is 3,576.

$$1,385 + 1,823 + 197 + 144 + 27 = 3,576$$

The number of cars in operation divided by the daily work load gives the turnaround time. Let the daily work load be 1,875 freight cars; then

$$\frac{3,576}{1,875} \approx 1.907 \text{ days}$$

For the sake of a round number, we must use the figure 1.91, not 1.90 days. The same result may be obtained by applying the proper figures in the turnaround-time formula given above.

$$\frac{1}{24}\left(\frac{315.6}{18} + \frac{315.6}{92.5} \times 3.7 + \frac{1,200 + 1,363}{1,875} \times 11.6\right) = 1.91 \text{ days}$$

III. ACTUAL TURNAROUND TIME

Let the actual number of freight cars in operation be 3,125, and the daily work load be 1,672. Then the actual turnaround time will be 1.87 days.

$$\frac{3,125}{1,672} = 1.87 \text{ days}$$

Taking the actual figures for all the relevant factors in the same cycle of operations and applying them in the formula, we get a different result.

$$\frac{1}{24}\left(\frac{296.1}{16.6} + \frac{296.1}{92.5} \times 4.2 + \frac{1,070 + 1,322}{1,672} \times 14.7\right) = 2.18 \text{ days}$$

The difference between 2.18 days and 1.87 days is 0.31 days. That is to say, for every 1,000 cars in operation, the daily difference in work done will be 76.05 cars.

$$\frac{1000}{1.87} - \frac{1000}{2.18} = 534.76 - 458.71 = 76.05 \text{ cars}$$

The monthly difference will be 76.05 X 30, or 2,281 cars. This is by no means a trifling discrepancy. We must study the reasons for such a difference.

IV. COMPARISON OF PLANNED AND ACTUAL TURNAROUND TIME

The following list facilitates comparison of the factors in the planned and actual turnaround times.

Factors	Planned	Actual	Comparison (%)
Average turnaround distance (TRD)	315.6	296.1	-6
Travel speed (TS)	18.	16.6	-8
Average distance between marshaling yards (DSM)	92.5	92.5	--
Average switching time (SWT)	3.7	4.2	+14
Number of cars loaded (CLD)	1,200	1,070	-11
Number of cars unloaded (CUN)	1,363	1,322	-3
Daily work load (DWL)	1,875	1,672	-12
Average stopping time (ST)	11.6	14.7	+27

A. Factors That Tend to Reduce Turnaround Time

The reduction in the average turnaround distance by 6 percent means a reduced total traveling time of all cars. It also means a reduced total switching time spent in switching stations.

B. Factors That Tend to Increase Turnaround Time

1. A reduction in travel speed by 8 percent means an increase in total travel time for all cars.

2. The increase of 14 percent in average switching time means an increase in the total switching time spent in marshaling yards.

3. Although the number of cars loaded shows a reduction of 11 percent and the number of cars unloaded shows a reduction of 3 percent, the daily work load shows a reduction of only 12 percent. By comparison, the proportion of accomplishment is greater by 4 percent: but this also means that the total stopping time at loading and unloading stations is greater.

$$\frac{1,200 + 1,363}{1,875} : \frac{1,070 + 1,322}{1,672} = 1.36 : 1.41 = 100 : 104$$

4. The increase of 27 percent in average stopping time means an increase in the total stopping time at the loading and unloading stations.

Thus there is only one factor that tends to reduce the turnaround time, and that one amounts to only 6 percent. But there are four factors showing increases of from 4 to 27 percent. Therefore, the actual turnaround time as calculated by the formula (2.18 days) should be worse than the planned turnaround time (1.91 days); it should not be better than the planned turnaround time. Nevertheless, the fact remains that the actual turnaround time, when derived by dividing the total number of cars in operation by the daily work load is 1.87 days. It is apparent that there is some discrepancy here. This must be examined.

There should be no question about the figures for cars loaded and cars unloaded and daily work load, because they are averages derived from actual count. There should be no significant discrepancy concerning the traveling speed and the average turnaround distance, even though they depend largely on effort. The problem boils down to the improvement of three factors, namely: average distance between marshaling yards or switching stations, average switching time, and average stopping time.

V. AVERAGE DISTANCE BETWEEN SWITCHING STATIONS

When using the turnaround-time formula, instead of the average distance between switching stations (DSM), the average switching distance (SWD) should be used. The latter is derived thus:

$$\frac{\text{Average Daily Kilometrage}}{\text{Average Daily Number of Cars Switched}} = \text{Average Switching Distance (SWD)}$$

However, what we have been using hitherto is derived thus:

$$\frac{\text{Total Aggregate of Distances Between Switching Stations}}{\text{Number of Space Intervals Between Switching Stations}} =$$

$$\text{Average Distance Between Switching Stations (DSM)}$$

These two things are not the same; indeed they are quite different. The average switching distance changes constantly according to the number of cars switched, which, in turn, depend on traffic conditions. The average distance between switching stations is constant, irrespective of the traffic.

Although both the number of cars traveling between switching stations and the distances between stations vary, on the average, approximately the same number of cars travel short distances as long distances. To find the average number of times that switchings take place, when the average turnaround distance is divided by SWD, and then by DSM, it is found that the difference between them is about "1".

$$\frac{TRD}{SWD} = \frac{TRD}{DSM} - 1$$

To illustrate:

$$A \longrightarrow B \longrightarrow C \longrightarrow D$$
$$\overrightarrow{\qquad\qquad\qquad\qquad\qquad}$$

In being transported from A to D, cars traverse three intervals between switching stations, but switching takes place only twice (at B and C), that is, one less time than the number of intervals between switching points.

It is a fact that commercial transportation conditions are very complex, and that for each turnaround distance, both loaded and empty cars travel between large marshaling yards, between small stations, and between marshaling yards and small stations. Speaking generally, it might seem a matter of small consequence to reckon the number of switchings as "1" more than the actual number. (See the section on Average Switching Distance of Freight Cars in Tsung Chih'lung's article entitled, "Discussion of Turnaround Time of Freight Cars Under the Northeast Railway Administration in 1950," published in the Jen'min T'ieh-tao Vol II, No 2, February 1950.)

However, if, when calculating the turnaround time, the figure used for the number of switching operations exceeds the correct figure by "1," the final result will be a turnaround time which includes time for one switching operation that did not actually take place. Hence the resultant turnaround time is not precise; and what is more, it makes the calculated turnaround time longer than it really is.

VI. AVERAGE SWITCHING TIME

In using the turnaround-time formula for freight cars, the figure taken for average switching time should be computed on the basis of two averages, namely, the average time for switching cars that are actually rearranged into different trains, and the average time spent in switching stations by through traffic cars which require no rearrangement. Hitherto, in China, statistics have been available for switched cars only, and none for through traffic cars. Manifestly, switching operations require more time than through traffic operations; yet in the past the average switching time for cars actually switched has been applied to the other cars as well. This figure, of course, is greater than the true average figure when the shorter time required for through traffic cars is taken into account. Hence, it is not fair to compare 4.2 hours of actual switching time with the planned average of 3.7 hours.

Although to date we have not recorded the number of through traffic cars, from general observation, we estimate that three fourths of the freight cars are actually switched, and one fourth are through traffic cars. Suppose that the average handling time at switching stations for through traffic cars is one hour; this figure would then apply to one fourth of the cars. The average switching time indicated above in the comparative table, 4.2 hours, should apply only to the three fourths which are actually switched. The correct overall average, therefore, would be

$$4.2 \times \frac{3}{4} + 1 \times \frac{1}{4} = 3.4 \text{ hours}$$

From this it can be seen that the real achievement of 3.4 hours is really better than the planned average switching time, 3.7 hours.

VII. AVERAGE STOPPING TIME AT TERMINALS

In using the turnaround-time formula, the figure taken for average stopping time at a terminal should depend on the average time required for the loading or unloading operation of one car. If an arriving car is unloaded and then reloaded in the same station, this should count as two operations. However, in China, it has been the practice, hitherto, to consider a car as the unit, rather than the loading or unloading operation.

According to this method, if a car were unloaded and reloaded in the same station, it was counted as one operation in computing the average stopping time. Naturally this results in a computed average stopping time greater than if each unloading and each loading is considered as a separate operation. The average stopping time of 14.7 hours, used in the foregoing computations, is based on the old method and obviously is not accurate. The proportion of incoming cars that are unloaded and reloaded at the same station is seldom more than 10 percent of the total number of cars handled at the station; it usually ranges between 5 percent and 10 percent. Let us take 6 percent as a conservative figure, then the adjusted average stopping time would be

$$14.7 \times \frac{100}{106} = 13.87 \text{ hours}$$

Although 13.87 hours is 20 percent larger than the planned average, it is smaller than 14.7 hours which is 27 percent larger than the planned average stopping time. The number 13.87 may be considered as approximately correct.

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VIII. CALCULATED TURNAROUND TIME AND ACTUAL TURNAROUND TIME

Of course, these derived figures cannot be considered completely accurate; but compared with the figures previously computed, they are much more reliable. Let us use them in the formula with planned and actual figures, and see what the results are.

A. Planned Turnaround Time

$$\frac{1}{24}\left\{\frac{315.6}{18}+\left(\frac{315.6}{92.5}-1\right)\times 3.7+\frac{1200+1363}{1875}\times 11.6\right\}=1.76 \text{ days}$$

B. Actual Turnaround Time

$$\frac{1}{24}\left\{\frac{296.1}{16.6}+\left(\frac{296.1}{92.5}-1\right)\times 3.4+\frac{1070+1322}{1672}\times 13.87\right\}=1.87 \text{ days}$$

The actual turnaround time as thus computed is the same as the figure obtained by dividing the number of cars in operation by the daily work load, (1.87 days). On the whole, the actual turnaround time is still not yet at the desired level, since 1.87 days exceeds the planned turnaround time (1.76) by some 6 percent. The reason is to be found in the fact that the traveling speed is less by 8 percent, the work performance ratio is greater by 4 percent, but the stopping time at terminals is greater by 20 percent. As for the switching time, it has surpassed the planned switching time, since it is less by 8 percent.

$$\left/\frac{3.7-3.4}{3.7}=8 \text{ percent}\right/$$

IX. SUGGESTIONS FOR IMPROVEMENT

It is obvious that in the application of the turnaround-time formula there are discrepancies between the planned time figure and the actual time figure. This fact affects the correctness of both the evaluation of performance and the efforts of our railroad workers. A remedy must be found. Therefore, the following suggestions are offered.

A. Adjusted Average Stopping Time at Stations

In computing this figure, the Chinese railways have taken cars as the unit, instead of one loading or unloading operation. It is not necessary that this practice be radically changed. To compute more accurately the average stopping time for one loading or unloading operation, a correction can be made easily by the use of a simple formula. To do this, it is necessary to record the number of arriving loaded cars that are unloaded and then reloaded at the same station each month, and determine the over-all average for all the stations. Let PC stand for the average monthly percentage of cars that are reloaded at the same station. Let ST stand for the average actual stopping time per car (as heretofore used). Let AST stand for the adjusted average actual stopping time per car, after making allowance for the fact that some cars are unloaded and loaded again at the same station. Then,

$$AST = ST \times \frac{100}{100 + PC}$$

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B. Adjusted Average Switching Time

To secure a more accurate figure for the over-all average switching time for use in the turnaround-time formula, it is recommended that the fact that through traffic cars are not actually switched at switching points be taken into account, as indicated in Part VI above. To accomplish this, it is necessary to keep records so as to be able to find the percentage which the over-all average number of switched cars as well as of through traffic cars, represent in the total number of cars passing through switching points. It is also necessary to gather data as to the average time required for handling the through traffic cars.

The adjusted average switching time (ASWT) will then be; the percentage of cars actually switched multiplied by the average switching time (SWT) plus the percentage of through traffic cars multiplied by the average time required for handling the through traffic cars.

C. Adjusted Average Switching Distance

Theoretically, the computation of the average actual switching distance is quite simple. All that is necessary is to divide the average daily kilometrage (average travel distance in kilometers) by the daily average number of cars switched. But when the planned turnaround time is to be computed, the process is far from simple. Two suggestions are offered.

1. From Actual Figures of Previous Month

Computation on the basis of the actual figures of the previous month is both simple and convenient, but not reliable. The average stopping time and the average switching time are comparatively fixed, but the average switching distance is apt to vary considerably from month to month due to changing traffic conditions. If the quantity of traffic between distant marshaling yards increases, but decreases between terminal points which are near each other, then the average switching distance will be greater; and if the reverse becomes true, the average switching distance will be shorter. Therefore, the computation of the average switching distance on the basis of the previous month's figures is not a satisfactory method.

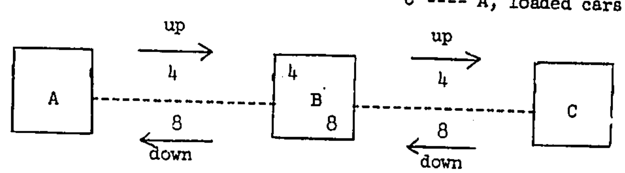
2. On Basis of Planned Traffic for Present Month

Computation on the basis of the present month's planned traffic is more accurate, but is far more complex. In computing the average switching distance, the number of cars actually switched is a very important factor and is one that demands care in recording data. This can be seen from an examination of a number of cases in which it is assumed that all the cars are boxcars, and that the number of cars and their points of origin and destination are known.

a. Loaded Cars

A ---- C, loaded cars 4

C ---- A, loaded cars 8



Altogether, 12 cars are switched at Switching Station B. Similar calculations should be made for other switching stations and for other types of cars.

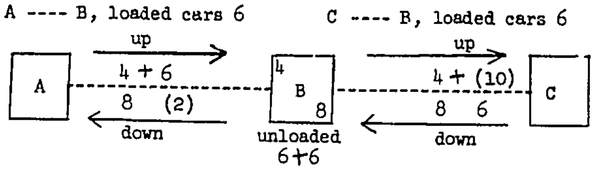
b. Empty Cars

(1) First Situation

If a train, moving either in the up direction, or in the down direction, has no empty cars attached, there will be no switching of empty cars.

A ---- C, loaded cars 4   C ---- A, loaded cars 8

A ---- B, loaded cars 6   C ---- B, loaded cars 6

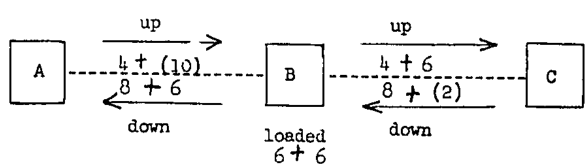


From the above diagram it can be seen that there are ten loaded cars moving up from station A to Station B, and only eight loaded cars moving down from Station B to Station A. To keep the balance, two empty cars must be sent down from B to A. There are four loaded cars moving up from Station B to Station C, and 14 loaded cars moving down from Station C to Station B. For the same reason, ten empty cars must be sent from B to C. Station B has 12 incoming loaded cars to be unloaded there. Of these, two are sent empty from B to A, and ten from B to C. There is no switching of empty cars.

(2) Second Situation

A ---- C, loaded cars 4   C ---- A, loaded cars 8

B ---- A, loaded cars 6   B ---- C, loaded cars 6

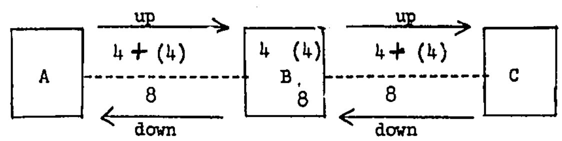


The above diagram shows that there are four loaded cars moving up from Station A to Station B and 14 loaded cars moving down from Station B to Station A. To keep the balance, ten empty cars must be sent from A to B. Between B and C, there are ten cars moving up and eight cars moving down. For the same reason, two empty cars must be sent from C to B. In this case, the 12 empty cars arriving at Station B will be loaded and six of them sent to A and six to C. Thus there is no switching of empty cars at Station B.

(3) Third Situation

If all empty cars are moved in one direction, either up or down, and if the number of incoming cars is the same as that of outbound cars, then the number of empty cars switched will be the number of incoming empty cars.

A ---- C, loaded cars 4   C ---- A, loaded cars 8



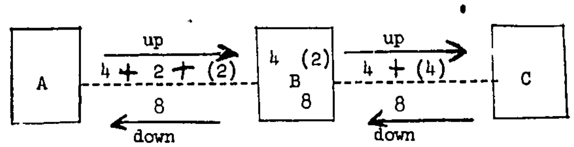
In the above diagram, there are four loaded cars moving up and eight moving down between Station A and Station B. To keep the balance, four empty cars must be sent from A to B. The situation between Station B and Station C is the same as that between A and B. At Station B the number of incoming and outgoing empty cars is the same. Therefore, the number of empty cars switched at Station B is four.

(4) Fourth Situation

If all empty cars go one way, in either direction, and if the humbers of outgoing and incoming empty cars are different, the smaller number will be the number of empty cars switched.

A ---- C, loaded cars 4   C ---- A, loaded cars 8

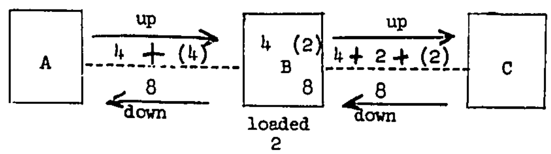
A ---- B, loaded cars 2



In the above example, there are six loaded cars moving up and eight loaded cars moving down between Station A and Station B. To keep the balance, two empty cars must be sent up from A to B. There are four loaded cars moving up from B to C and eight loaded cars moving down from C to B. For the same reason, four empty cars must be sent up from B to C. Station B has two incoming loaded cars, which, after being unloaded, will be added to two empty switched cars and the four empty cars will be sent from B to C. Hence, only two empty cars are switched. /The other two empties sent to station C were not switched; they stopped for unloading, and then started again./

A ---- C, loaded cars 4 C ---- A, loaded cars 8

B ---- C, loaded cars 2



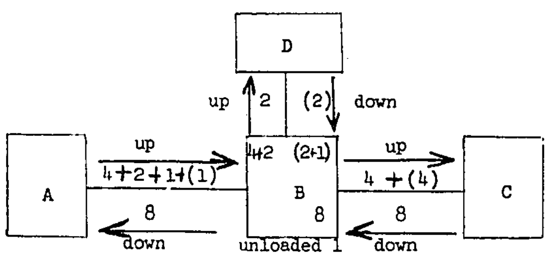
The above diagram shows four loaded cars moving up and eight moving down between Stations A and B. To keep the balance, four empty cars must be sent from Station A to Station B. There are six loaded cars moving up and eight moving down between Stations B and C. For the same reason, two empty cars must be sent up from B to C. Having received four empty cars from Station A, Station B retains two of them for subsequent disposition, and switches two of them for forwarding to Station C.

(5) Fifth Situation

In the case of switching stations for three or more directions, make a comparison between the total number of incoming empty cars and outgoing empty cars; the smaller number is the number of empty cars switched.

A ---- C, loaded cars 4 C ---- A, loaded cars 8

A ---- D, loaded cars 2 A ---- B, loaded cars 1



In the above diagram, there are seven loaded cars moving up and eight moving down between Station A and Station B. To keep the balance, one empty car must be sent up from A to B. There are four loaded cars moving up and eight loaded cars moving down between station B and C. For the same reason, four empty cars must be sent up from B to C. There are two loaded cars moving up and no loaded cars moving down between Stations B and D. Therefore, two empty cars must be sent down from D to B. Having received one empty car from Station A and two empty cars from Station D, with the addition of one car unloaded, Station B sends four empty cars up to Station C. Of these four empty cars, only three have been switched.

Thus it is possible to reckon the number of boxcars switched, both loaded and empty. The same method can be applied to gondola, flat, hopper, and tank cars. The planned average switching distance is obtained by dividing the planned daily average kilometrage of all types of cars combined, by the daily average total number of all types of cars that are actually switched.

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X. CONCLUSION

Since the matter is so important and has been given so much attention, turnaround time and its related factors must be accurately determined before they can be applied to the determination of goals to be achieved through loyal and well-directed effort. One percentage of effort must be accompanied by one percentage of achievement, otherwise working morale will be affected. With the exception of those in the Northeast, the railway bureaus of intramural China operate under much the same conditions. It is hoped that this article will stimulate its readers to study this problem and make suggestions for improvement.

- E N D -